Understanding Productivity and Income Differentials Among OECD Countries: A Survey

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INTRODUCTION

The growth experience in the period 1995-2001 in OECD countries represents a major break from the slow growth performance of the previous two decades or so. First, in the mid-1990s economic growth in most OECD countries, notably in the United States, greatly accelerated. Second, across OECD countries the variation in output growth, and more specifically in productivity performance, increased substantially. And third, despite the slowdown in growth during the years 2000 and 2001, the underlying trend in productivity growth begun in 1995 held up. Indeed the United States experienced only a minor slowdown in productivity growth in 2001, whereas Europe and Canada continued along a path of slow productivity growth beginning in the mid-1990s.

An analysis of these trends and an explanation for differences over time and across countries are important for several reasons including the study of social progress. Productivity measures the effectiveness with which inputs (materials, capital and labour) are transformed into output. This transformation process is accommodated for by continuous improvements in the quality of inputs, such as a rise in educational attainment, the creation of knowledge, organizational changes within firms or the setting up of societal networks. All of these factors, which I refer to as intangible investments in the economy, facilitate allocation of inputs to their most productive uses.

Productivity — in this paper, more specifically labour productivity — is important for social progress for two reasons. The first and more obvious reason is that, together with a greater use of labour, productivity positively contributes to per capita income, which is a reasonable proxy for living standards in a country.[1] The second reason is that labour-productivity growth often reflects the accumulation of intangible capital, which itself contributes to social progress, as workers become equipped with more human capital, more knowledge and access to networks, and which may ultimately even lead to the creation of more social capital.[2]

This paper is intended to contribute to our understanding of the link between economic performance and social progress, by reviewing some of the reasons for differences in growth and levels of productivity and per capita income in OECD countries. Figure 1 presents a conceptual framework for studying sources of growth and productivity differentials. This framework is rooted in a traditional growth accounting framework but has several crucial extensions. For instance, it shows the importance of both productivity and increased labour participation in driving growth in per capita income. The next section documents the most recent evidence on this with preliminary estimates up to 2001. It shows that much of the recent growth in per capita income in Europe (and Canada) is driven by a rise in employment/population ratios, although partly offset by a decline in the number of average annual working hours per person. The strong rebound in employment growth in Europe beginning in the mid-1990s has been quite welcome after many years of relatively low rates of labour force participation. But the expansion takes place along a track of slow productivity growth. In contrast, the United States seems to have embarked on an expansion along a high productivity growth path in combination with greater labour utilization.

To investigate the forces behind productivity growth, one can adopt one of two approaches or — ideally — a combination of the two. The first is to look at the sources of growth from the perspective of factor inputs, in particular capital, and their contribution to productivity at the aggregate level. The second is to investigate the contribution of industries to productivity growth, which may be the result of either productivity advances within industries or shifts of resources from low-productivity to high-productivity industries.

Various authors have argued that the recent American productivity advances are due to large investments in information and communications technology (ICT) goods and services and to productivity advances in the ICT-producing sector of the economy (Jorgenson and Stiroh 2000; Oliner and Sichel 2000; Jorgenson 2001). This paper discusses the sparse results available so far on the contribution of ICT capital *vis-à-vis* other physical capital to productivity growth across countries. The evidence suggests an acceleration of ICT investment in most OECD countries, but the contributions of ICT capital to output and productivity growth are generally lower in Europe (and Canada) than in the United States. Unfortunately, for most countries we still lack sufficient data on ICT capital at the industry level to investigate whether the differences in ICT-capital contributions are not at least partly due to differences in industry composition, such as the United States having a larger ICT production sector.

We therefore proceed by looking at the contributions to aggregate labour-productivity growth from the perspective of three subgroups of industries: those classified as producers of ICT goods and services, those that typically are intensive users of ICT, and those that are less intensive users of ICT. The results suggest substantial differences in the productive use of ICT. It also appears that the strong employment growth in European economies is concentrated in industries that are typically not regarded as big users of ICT. Productivity in this group of less-intensive ICT users grows more slowly than elsewhere in the economy, particularly in European countries compared to the United States. Differences in ICT investment and intensity are therefore unlikely to account for the whole story on cross-country productivity differentials.

FIGURE 1
Analytical Framework of Sources of Growth

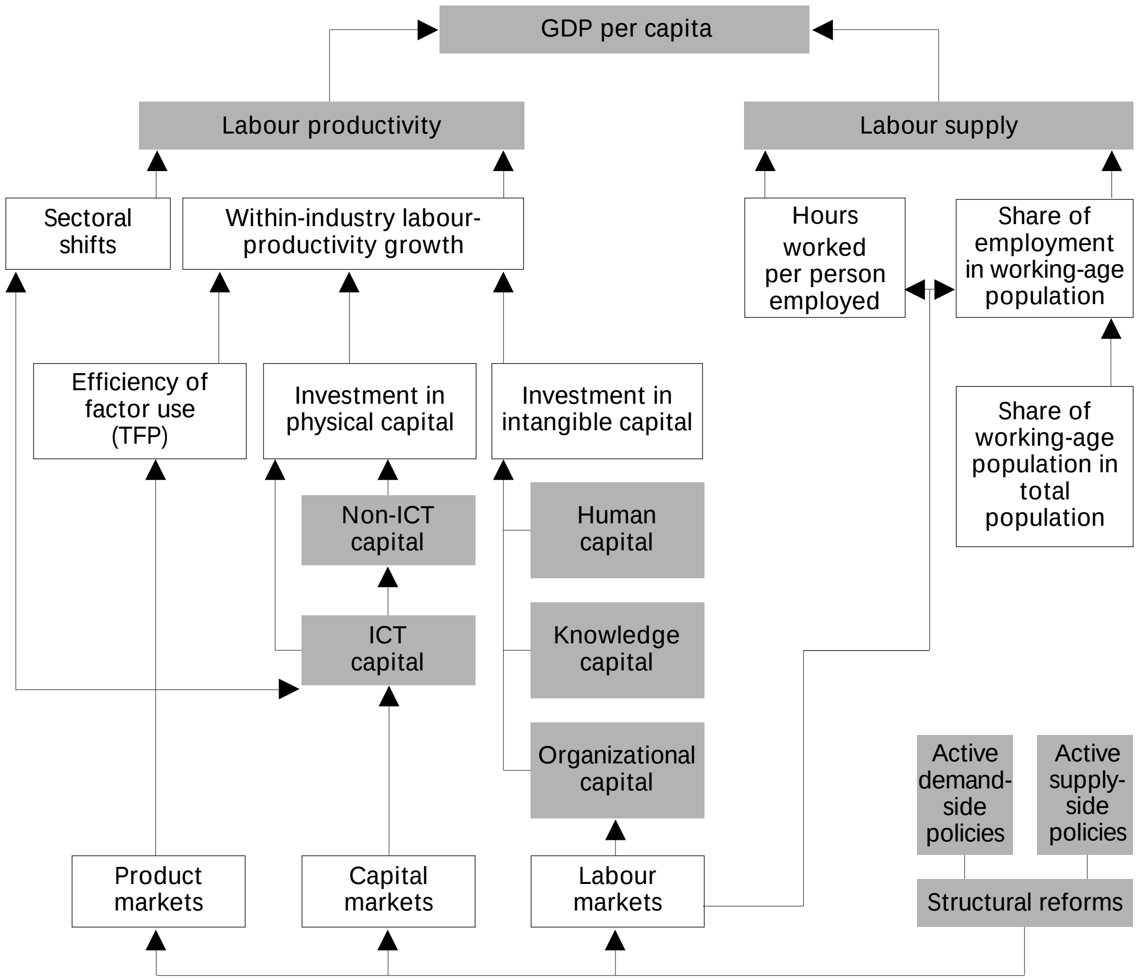


Figure 1 shows that within-industry productivity growth is driven by a second type of investment, namely that in intangible capital. The final section of the paper focuses on differences in the creation of intangible capital that may account for some of the cross-country differentials in productivity growth and levels. Although other classifications are possible, I distinguish among human capital, knowledge capital and organizational capital as components of intangible capital. Using recent numbers from the OECD, which include those components of intangible capital that are easiest to quantify (software, formal higher education, R&D), I find only a weak relation between intangible expenditures and either productivity growth or productivity levels. However, I also argue that a larger effect of intangibles is likely to be found in the organizational component of intangible capital. In the conclusion, I summarize the implications for the link between productivity and social progress and I briefly outline the agenda for further research.

LABOUR PRODUCTIVITY AND INCOME PERFORMANCE IN OECD COUNTRIES

Labour productivity and per capita income are two key measures of economic performance. Per capita income is a reasonable (but incomplete) proxy for living standards. The attractive feature of this measure is that it can be easily linked to labour productivity, thereby opening up the comprehensive framework for investigating the sources of growth by way of growth accounting. Table 1 summarizes per capita income and productivity growth rates for Canada, the United States and the European Union for the periods 1990-95 and 1995-2001.[3] It shows that all three experienced a substantial improvement in per capita income growth in the latter period. In 2001, output growth collapsed across the OECD, but the

TABLE 1

Summary Growth Rates of Per Capita Income, Labour Productivity and Total Hours Worked, Canada, European Union and United States

	Canada	European Union[1]	United States
	Per Capita Income Growth (%)		
1990-1995	0.3	1.0	1.4
1995-2001	1.9	2.1	2.6
of which:			
1995-2000	2.2	2.3	3.1
2000-2001	0.3	1.5	0.2
Change in growth rates			
1995-2001 over 1990-1995	1.5	1.1	1.3
2001 over 1995-2000	-1.9	-0.7	-3.0
	Labour-Productivity Growth (%)		
1990-1995	1.3	2.5	1.1
1995-2001	0.9	1.3	2.0
of which:			
1995-2000	1.0	1.4	2.0
2000-2001	0.2	0.6	1.8
Change in growth rates			
1995-2001 over 1990-1995	-0.4	-1.2	0.9
2001 over 1995-2000	-0.9	-0.8	-0.2
	Total Hours Worked (%)		
1990-1995	0.2	-1.0	1.2
1995-2001	2.2	1.2	1.6
of which:			
1995-2000	2.5	1.2	2.0
2000-2001	0.7	1.1	-0.7
Change in growth rates			
1995-2001 over 1990-1995	2.1	2.2	0.3
2001 over 1995-2000	-1.9	-0.1	-2.7

[1] European Union is weighted average for 14 EU member countries, excluding Luxembourg

Source: Groningen Growth & Development Center & The Conference Board. See McGuckin and van Ark (2002). Based on OECD National Accounts, Economic Outlook, Employment Outlook and Labour Force Statistics, with GDP converted to US$ at 1996 EKS PPPs.

United States appears to be the hardest hit. When the focus is labour-productivity growth, however, the changes in growth rates differ greatly across countries. Whereas the United States experienced a strong acceleration, in both Canada and the European Union productivity growth began to slow down in the mid-1990s.[4] Furthermore, during 2001 productivity slowed much less in the United States than in Canada and Europe.

Differences among countries in terms of growth or relative levels of per capita income and labour productivity are determined by differences in the number of annual working hours per person employed and the share of the population at work. For example, even when two countries have the same productivity levels, a less intensive use of labour — fewer hours of work, more unemployment, lower labour participation rates — can cause one country to have lower per capita income than the other. This relationship can be conveniently expressed in a decomposition linking differences in per capita income and productivity. First, the relative difference in per capita income (*O/P*) between two countries (*X* and *US*) is expressed as the relative difference in labour productivity times the relative difference in labour input per person (*H/P*):

$$O/P^{\,x\text{-}us} = (O/H)^{x\text{-}us} * (H/P)^{x\text{-}us} \qquad (1)$$

Then, the differences in working hours per person are decomposed into differences in hours worked per person employed *(H/E)* and the share of employment in the total population *(E/P)*:

$$H/P^{\,x\text{-}us} = (H/E)^{x\text{-}us} * (E/P)^{x\text{-}us} \qquad (2)$$

The employment/population ratio *(E/P)* can be further broken down into the number of persons employed relative to the total labour force *(E/L)* (i.e., employed persons plus registered unemployed persons), the ratio of the labour force to all persons aged 15 to 64 (*L/P*1564) (i.e., the working-age population) and the share of the working-age population in the total population (*P*1564/*P*) (see van Ark and McGuckin, 1999):

$$(E/P)^{x\text{-}us} = (E/L)^{x\text{-}us} * (L/P1564)^{x\text{-}us} * (P1564/P)^{x\text{-}us} \qquad (3)$$

Table 2 shows the relative levels of GDP per capita and labour productivity in 2001. The countries are ranked according to level of per capita income. These estimates are based on the most recent but still preliminary estimates for GDP, employment and hours derived from OECD national accounts and labour force statistics. GDP is converted from national currency to US dollars at 1996 purchasing power parities.[5]

The estimates show that the United States has by far the highest per capita income. Norway comes next, at 17 percentage points (or 5,500 US$) behind the United States. The European Union as a whole is 33 percentage points (or 11,000 US$) behind the United States. Canada is 23 percentage points (or 7,500 US$) behind the United States.

Productivity differences between the United States and most follower countries are considerably smaller than the per capita income differences. In fact, as many as four countries have a higher level of GDP per hour than the United States, namely Belgium (4.5 US$ per hour higher), Norway (3.5 US$), and the Netherlands and France (about 0.5 US$). Indeed the productivity level of the European Union as a whole falls only 13 percentage points (4.5 US$) behind that of the United States, which is 20 percentage points less than the distance between EU and US levels in terms of per capita income. Some 12 percentage points of the 20-percentage-point difference between the EU/US productivity gap and the

TABLE 2

Reconciliation of GDP Per Capita and Labour Productivity, OECD Countries, 2001 (preliminary estimates)

	GDP Per Hour Worked[1]		Effect of Working Hours[1]	Effect of Employment Share in Total Population (in % points)				GDP Per Capita	
	in 1996 US$	as % of US	in % points	Unemployment[2]	Labor Force to Population (15-64 yrs)	Population (15-64 yrs) to Total Population	Total[3]	in 1996 US$	as % of US
United States	36.97	100.0	0.0	0.0	0.0	0.0	0.0	33,538	100.0
Norway	40.55	109.7	-28.9	1.0	3.1	-1.6	2.5	27,940	83.3
Ireland	36.36	98.4	-8.8	0.6	-9.7	1.0	-8.1	27,318	81.5
Switzerland	31.73	85.8	-12.8	2.1	5.5	0.6	8.2	27,236	81.2
Denmark	34.58	93.5	-16.4	0.1	2.4	0.4	2.9	26,857	80.1
Canada	30.53	82.6	-3.5	-2.1	-1.2	1.5	-1.8	25,923	77.3
Australia	30.32	82.0	-3.1	-1.7	-1.7	1.5	-1.9	25,818	77.0
Belgium	41.54	112.4	-18.9	-2.1	-15.4	-0.7	-18.2	25,252	75.3
Netherlands	37.32	100.9	-28.1	1.5	-1.1	1.3	1.7	24,989	74.5
Austria	35.46	95.9	-17.9	0.8	-6.3	1.5	-4.0	24,828	74.0
Japan	26.64	72.1	-2.7	-0.1	1.4	1.7	3.0	24,267	72.4
Finland	31.92	86.3	-10.7	-3.4	-2.2	0.9	-4.7	23,795	71.0
Sweden	30.22	81.7	-10.7	-0.3	1.7	-2.0	-0.5	23,636	70.5
Germany	34.20	92.5	-16.6	-2.5	-5.1	1.0	-6.6	23,247	69.3
France	37.63	101.8	-17.8	-3.6	-9.6	-1.6	-14.8	23,176	69.1
Italy	32.53	88.0	-11.0	-4.1	-5.2	0.9	-8.4	22,991	68.6
United Kingdom	29.40	79.5	-9.2	-0.2	-1.8	-0.6	-2.7	22,696	67.7
Spain	27.93	75.6	-1.8	-6.6	-12.2	0.9	-18.0	18,723	55.8
New Zealand	22.49	60.8	-3.6	-0.3	-0.7	-0.8	-1.9	18,560	55.3
Korea	15.18	41.1	13.6	0.4	-8.4	3.3	-4.7	16,747	49.9
Portugal	19.25	52.1	-3.1	0.3	-1.1	1.2	0.4	16,548	49.3
Greece	21.64	58.5	2.4	-3.9	-10.9	0.7	-14.1	15,696	46.8
Czech Rep.	14.43	39.0	3.2	-1.5	-3.0	2.0	-2.5	13,346	39.8
Hungary	17.44	47.2	-1.8	-0.5	-10.8	1.0	-10.4	11,730	35.0
Poland	11.90	32.2	2.7	-4.8	-4.2	1.1	-7.9	9,021	26.9
Mexico	12.13	32.8	3.0	0.9	-9.6	-2.7	-11.5	8,156	24.3
Turkey	10.16	27.5	1.1	-0.9	-10.2	0.2	-10.9	5,933	17.7
European Union[4]	32.30	87.4	-12.1	-2.4	-6.0	0.2	-8.2	22,511	67.1
OECD excl. US	24.87	67.3	-2.8	-1.5	-7.0	0.1	-8.4	18,818	56.1

[1] Calculated on basis of actual hours worked per person per year.
[2] Calculated on basis of standardized unemployment rates from OECD.
[3] Sum of previous columns plus rounding differences.
[4] European Union is weighted average for 14 EU member countries, excluding Luxembourg.
Source: Groningen Growth & Development Center & The Conference Board. See McGuckin and van Ark (2002). Based on *OECD National Accounts, Economic Outlook, Employment Outlook* and *Labour Force Statistics*, with GDP converted to US$ at 1996 EKS PPPs.

EU/US income gap can be explained by fewer working hours per person employed in the European Union (1,609 hours) than in the United States (1,868 hours). Another nine percentage points are due to the ratio of employed persons *vis-à-vis* the total population, 0.43 percent in the

TABLE 3

Growth of GDP Per Capita and Labour Productivity and Differences in Labour Market Indicators, Canada, European Union and United States

	GDP/Capita (US 1990=100)			GDP/Hour Worked (US 1990=100)		
	Canada	European Union[1]	United States	Canada	European Union[1]	United States
1990	85.2	70.2	100.0	87.4	85.4	100.0
1991	82.5	70.6	98.5	88.9	88.1	101.0
1992	82.3	71.3	100.4	91.8	90.4	104.0
1993	83.4	70.7	102.0	92.1	92.3	104.3
1994	85.7	72.4	105.1	92.0	95.0	105.4
1995	86.5	73.9	107.0	93.4	96.6	105.8
1996	86.7	74.9	109.8	92.9	97.7	108.2
1997	88.0	76.5	113.6	94.4	99.7	109.9
1998	89.9	78.5	117.3	95.8	100.5	112.0
1999	93.1	80.2	121.0	97.2	101.5	114.3
2000	96.4	82.7	124.9	98.3	103.5	117.1
2001[2]	96.7	84.0	125.1	98.5	104.2	119.2
	Hours Per Person Employed			Employment/Population (15-64) Share		
	Canada	European Union[1]	United States	Canada	European Union[1]	United States
1990	1799	1657	1819	0.468	0.429	0.475
1991	1764	1637	1808	0.455	0.423	0.466
1992	1736	1633	1799	0.447	0.417	0.464
1993	1760	1624	1815	0.445	0.408	0.466
1994	1789	1624	1825	0.449	0.406	0.472
1995	1771	1621	1840	0.452	0.408	0.475
1996	1789	1619	1838	0.451	0.409	0.477
1997	1782	1616	1848	0.452	0.410	0.483
1998	1766	1620	1864	0.459	0.417	0.486
1999	1772	1617	1872	0.467	0.422	0.489
2000	1789	1609	1879	0.474	0.429	0.491
2001[2]	1789	1609	1868	0.475	0.433	0.486

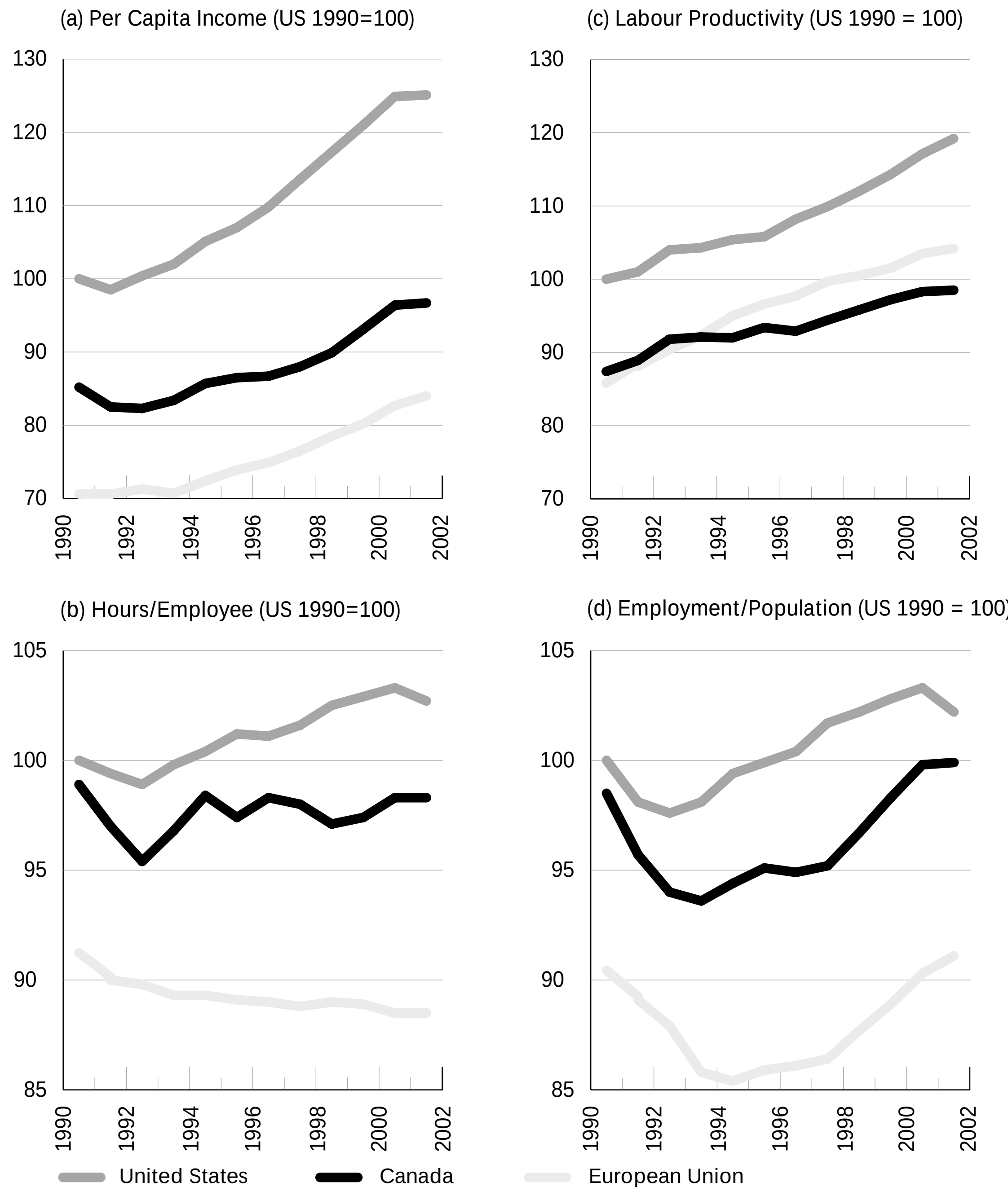
[1] European Union is weighted average for 14 EU member countries, excluding Luxembourg.
[2] Preliminary estimate.
Note: US hours based on total working hours from BLS Productivity Database divided by total numbers of employed persons from BLS CPS; Canadian hours from CSLS Productivity Database. European average hours from GGDC Total Economy Database.
Source: Groningen Growth and Development Center & The Conference Board (http://www.eco.rug.nl/ GGDC/index-dseries.html). See McGuckin and van Ark (2002).

European Union and 0.49 percent in the United States. Most of the difference in the employment/population ratio is a result of the share of the labour force in the working-age population ($L/P1564$).

In the case of Canada, the productivity gap is 18 percentage points and the per capita income gap is 23 percentage points, for a difference of five percentage points. Three of those percentage points are due to Canada's fewer working hours per person (1,789 hours) and two are due to its lower employment/population ratio (E/P), with some offsetting effects between higher unemployment ($1\text{-}E/L$) and lower labour force participation ($L/P1564$) on the one hand and a somewhat larger working-age population share in the total population on the other ($P1564/P$).

CHART 1

Reconciliation of GDP Per Capita and Labour Productivity, Canada, US and European Union



The lower levels of working hours and labour force participation in both the European Union and Canada relative to the United States in 2001 are characteristic of the 1990s (and indeed of the two preceding decades). Until 1997, labour force participation and working hours increased at a much slower rate in these countries than in the United States (Table 3 and Chart 1). In contrast, until about the same time productivity in the follower countries increased faster than in the United States, reflecting their long run process of catching up after the Second World War. Since 1997, however, labour force participation has increased more rapidly in Europe and Canada than in the United States. Yet it still has not led to a further narrowing of the income gap, for two reasons. First, working hours per person continued to decline, particularly in Europe, because of labour time shortening schemes (such as in France and Germany) and the creation of many part-time jobs (such as in the Netherlands). Second, since 1995 productivity growth in the United States has zoomed ahead of both Europe and Canada, which is the main topic of the next section.

In conclusion, at least two factors may have contributed to slower income growth in Europe and Canada relative to the United States during the 1990s. The first is different labour market arrangements, leading to underutilization of the labour potential in Europe and Canada. This explanation dominated the differences in income trends until the mid-1990s. The second factor is slower productivity growth in Europe and Canada. This has been the main explanation for better income performance in the United States in the 1995-2001 period. The search for an explanation for recent differences in per capita income performance should therefore concentrate on the reasons for the differences in productivity growth in 1995-2001.

THE ROLE OF ICT CAPITAL

The rapid increase in ICT investment is seen by many as a key explanation for the acceleration of productivity growth in the United States (OECD 2000*a*, 2001*a*). Some stress that this acceleration is to a large extent due to improved productivity growth in the ICT-producing sector (Jorgenson and Stiroh 2000; Jorgenson 2001). Others point to the increasingly productive use of ICT goods and services elsewhere in the economy (Oliner and Sichel 2000; Baily and Lawrence 2001). Most authors, however, agree that investment in ICT has been heavy and widespread in the United States.[6]

Although the international evidence on the impact of ICT capital on growth is still sparse, there are some comparative growth accounting studies that compile ICT investment as a separate factor input. These studies mostly derive information on ICT expenditure from (private) data sources (e.g., Schreyer 2000; Goldman Sachs 2000; Daveri 2001). The latter include consumer expenditure, which needs to taken out on the basis of crude assumptions to arrive at proxies for ICT investment.

Only recently have attempts been made to obtain genuine investment series for ICT (Colecchia and Schreyer 2001; ECB 2001). The top panel of Table 4 compares the acceleration of real investment growth in ICT in the United States, Canada and five European countries (Finland, France, Germany, Italy and the United Kingdom) for the periods 1990-95 and 1995-99.[7] ICT investment includes IT goods, communications equipment and software. The figures show that throughout the 1990s growth in ICT investment was quite high, and not only in the United States. Canada even experienced a faster rise in ICT investment than the United States during the second half of the 1990s. Moreover, many countries have experienced a greater acceleration of ICT investment than the United States: Canada,

TABLE 4

Growth of ICT Investment[1] and Contribution of ICT to Output Growth, Canada, US and Selected European Countries

	Canada	United States	Euro-5[2]	Finland	France	Germany	Italy	UK
	Growth of ICT investment in constant prices							
1990-1995	12.0	13.5	11.6	9.4	14.4	8.8	6.9	18.9
1995-2000[3]	22.8	21.3	17.6	21.0	15.7	17.7	16.3	19.8
Acceleration	10.8	7.8	5.9	11.6	1.2	8.9	9.4	0.9
	Share of ICT investment in total non-residential investment							
1990	13.2	22.5	12.3	13.2	9.4	13.9	13.7	10.1
1995	16.8	26.1	13.7	16.8	10.8	13.3	14.4	15.6
2000	21.4	29.9	15.8	24.1	14.4	16.2	16.3	15.0
	Contribution of ICT services to output growth							
1990-1995	0.30	0.43	0.25	0.24	0.18	0.30	0.21	0.27
1995-2000[3]	0.57	0.87	0.38	0.62	0.33	0.35	0.36	0.47
Acceleration	0.27	0.44	0.13	0.38	0.15	0.05	0.15	0.20

[1] Includes information technology, communications equipment and software.
[2] Five European countries, which are the only ones available from Colecchia and Schreyer (2001), are weighted at ICT-investment shares from Mulder et al. (2001).
[3] For Finland and Italy data are available only up to 1999.
Source: Calculated from Colecchia and Schreyer (2001) and Mulder et al. (2001).

Finland, Germany and Italy all show greater improvement in ICT investment than the United States.

To estimate the contribution of ICT to productivity growth, one must transform the ICT investment numbers into a measure of ICT capital. This is usually done by cumulating the investment figures over the years and applying certain assumptions about the service lives and scrapping patterns of the assets (the "perpetual inventory method"). Service lives of ICT capital goods are substantially shorter than those of other capital goods, which raises the pace at which old capital goods are replaced by new capital goods. Following Schreyer (2000) and Colecchia and Schreyer (2001), output growth (Q) can decomposed into:

$$\hat{Q} = s_L\hat{L} + s_{KC}\hat{K}_C + s_{KN}\hat{K}_N + \hat{A} \qquad (4)$$

where L is labour input, K_C is ICT capital, K_N is all other physical capital and A represents total factor productivity, with the latter being measured as a residual (the hats on the variables indicate percentage rates of change). Labour and capital services are weighted at the share of their respective revenues in total factor income.[8] The bottom panel of Table 4 shows the contribution of ICT capital (K_c) to output growth. Colecchia and Schreyer find a higher ICT contribution for the United States than for the other countries, with the exception of Finland.[9] Indeed the larger share of ICT investment in expenditure (also shown in Table 4), not the faster growth rate of ICT investment, accounts for the greater contribution from ICT capital in the United States. Daveri (2001), who covers a larger group of countries but uses adjusted ICT expenditure proxies for investment, largely confirms these results. He finds that the contribution of ICT capital to GDP growth in

European countries varied between 0.31 and 0.64 percentage points over the period 1991-99, compared to 0.94 percentage points in the United States. In an earlier version of his paper, Daveri (2000) also produced estimates for non-European countries, including Australia and Canada, which showed ICT contributions as large as those for the leading group of European countries such as the United Kingdom and the Netherlands.[10]

In this paper we do not go into many of the methodological details concerning the calculation of the contribution of factor inputs to growth, and the interpretation of total factor productivity that emerges as a residual from any growth accounting study. These have been the subject of a long debate that is well summarized in a recent survey article by Hulten (2001). From the perspective of using ICT as a separate capital good in the production function, one of the fundamental problems is the constant returns that characterize the production function and that assume there can be no "supra-normal" returns from ICT beyond that of other capital goods.[11]

Another issue concerns the assumption of Hicks-neutral technical change, which implies that technological progress increases output without changing the proportional distribution among the factor inputs. This viewpoint can be challenged for at least two reasons. First, a distinction can be made between the fraction of investment that is required to keep the capital/output ratio constant (given the state of technology) and the fraction that is induced by the innovations themselves. The latter represents the part of investment that contributes to the outward shift of the production function and therefore represents technological change rather than accumulation.[12] Second, it is generally asserted that ICT is not neutral to the use of factor inputs, as it is typically characterized by high capital-skills complementarity (Berman, Bound and Machin 1998). Although the latter issue is relevant from the perspective of investment in intangible capital, which will be discussed in the last section, I have not tried to resolve the links between the factor inputs that go beyond measuring to also explain productivity differentials among countries.

At this stage suffice to note that the figures reported in Table 4 suggest that ICT investment is one of the causes of slower productivity growth in Europe and Canada compared to the United States. However, even though for most countries the contribution of ICT to output growth is lower than that of the United States, one would expect at least some acceleration in labour-productivity growth (Table 1). Instead, despite the acceleration of ICT investment, labour-productivity growth in many European countries and Canada actually decelerated.

THE ICT-USE DIFFERENTIAL

As many countries still lack the necessary statistics, disaggregation of ICT investment by industry is not possible in the framework of international comparison. An alternative approach is to focus on labour productivity, which requires only output and employment data by industry. Van Ark (2001*b*) compares the contributions to overall labour-productivity growth of three groups of industries: ICT-producing industries; intensive ICT-using industries; and industries that use ICT less intensively, hereafter referred to as "non-ICT" industries. This approach can shed light on the role of ICT in growth, for several reasons. First, a strong presence of ICT-producing industries (i.e., hardware and software producers), as is the case in the United States and Finland, is in itself an explanation for a greater contribution of ICT investment to growth. Second, a large ICT-producing sector may facilitate the process of diffusing ICT to industries that are major users. Third, some industries in the economy are much more intensive ICT users than others. Particularly intensive users are in found in business and producer services (McGuckin and Stiroh 2001). These are relatively large industries in which most of the employment creation of the past decade was concentrated and which therefore are key to the acceleration of productivity growth. This also implies that a sectoral composition biased against those industries may be a reason for slower productivity growth at the aggregate level.

The precise shares of the three ICT categories in total output depend on the definition of ICT-producing industries and on the empirical distinction between ICT-using industries and non-ICT industries. ICT-producing industries as defined by the OECD include computer hardware and software producers, computer services, and telecommunications equipment and services (OECD 2000*b*). For the definition of ICT-using industries, van Ark (2001*b*) used estimates of ICT investment/output ratios by industry as well as the industry shares of ICT capital for two countries, the United States and the Netherlands.[13] About one third of industries with the highest ICT intensity and/or the highest shares in ICT capital stock are defined as ICT-using industries.

The first two columns of Table 5 show that the output shares of the ICT-producing sector are quite low across the board. Even for the United States the share of ICT production in total economy output is less than 7.5 percent of current-dollar GDP in 1999. With the exception of Finland, the shares of the ICT-producing sector in nominal output increased only slightly. The differences in output shares are mainly due to larger shares of ICT manufacturing industries in Japan, the United States and Finland.

The third and fourth columns of Table 5 show the shares of ICT-using industries in GDP. The United States is again characterized by larger output shares than all the other OECD countries except the Netherlands. However, the differences in output share of the ICT-using sector are smaller than for the ICT-producing sector. The differences in shares between the ICT-using sector are due to differences in industry composition across countries. For example, the relatively high output share for the Netherlands is due to the larger share of chemicals in ICT-using manufacturing and of business services in ICT-using services. To measure the contribution of the ICT producing sector, the ICT-using sector and the non-ICT sector to the growth of labour productivity, a traditional shift-share analysis was employed. This implies that labour productivity for the total economy (P) can be perceived as the sum of the productivity contributions of three sectors (i) distinguished above weighted at their labour share ($L_i/L=S_i$):[14]

$$P = \frac{Y}{L} = \sum_{i=l}^{n} \left(\frac{Y_i}{L_i}\right)\left(\frac{L_i}{L}\right) = \sum_{i=l}^{n} (P_i S_i)$$

Table 6 shows the contribution of the ICT-producing sector, the ICT-using sector and the non-ICT sector to the growth of labour productivity from 1990 to 1999, with the period being divided into two sub-periods, 1990-95 and 1995-99.[15] In the United States, the ICT-producing sector and the ICT-using sector together accounted for almost two-thirds of labour-productivity growth during the latter period (0.6 + 1.4 as a share of 2.5). In all other countries except Finland the combined contri-

TABLE 5

Output Shares of ICT-producing, ICT-using and Non-ICT Industries, Selected OECD Countries, 1990 and 1999 (as % of GDP at current basic prices)

	ICT-producing Industries as % of Total Economy[1]		ICT-using Industries as % of Total Economy[2]		"Non-ICT" Sector as % of Total Economy	
	1990	1999	1990	1999	1990	1999
Canada[3]	4.2	4.8	20.3	20.9	75.5	74.3
Denmark	4.3	4.7	18.5	19.2	77.2	76.1
Finland	4.6	9.6	16.3	16.3	79.1	74.1
France[4]	5.0	5.3	19.6	19.4	75.4	75.3
Germany[5]	5.4	5.3	21.0	20.8	73.6	73.9
Italy	4.4	5.0	21.2	21.6	74.4	73.4
Japan[4]	6.0	6.3	22.0	21.4	72.0	72.3
Netherlands	4.5	5.5	22.9	25.4	72.6	69.1
United Kingdom	5.7	7.0	21.6	22.4	72.7	70.6
United States	6.5	7.3	21.0	25.0	72.5	67.7

[1] The ICT-producing sector consist of IT hardware, radio, television and communication equipment, medical appliances and instruments and appliances for measurement (together the ICT industry) and telecommunication and computer services (together ICT services).
[2] The distinction between intensive ICT-using industries and "non-ICT" industries is largely based on studies by McGuckin and Stiroh (2001) and the National Science Foundation (2000) for the United States, making use of ICT investment/output ratios and ICT capital stock shares by industry.
[3] For Canada, value added at current prices for 1999 is derived by extrapolating 1996 current price estimate to 1999 with index in constant prices and using average deflators for 1990-1996.
[4] For France and Japan for 1998.
[5] For Germany for 1991 and 1998.
Source: Van Ark (2001*b*).

bution of ICT production and ICT use was lower in absolute terms.[16] Table 6 also shows that in almost all countries ICT production (with the exception of Denmark) and ICT use (with the exception of Italy and to a lesser extent Japan and the United Kingdom) contributed positively to *acceleration* in labour-productivity growth during the second half of the 1990s compared to the first half. However, in several European countries, notably Denmark, Finland, Germany, Italy, the Netherlands and the United Kingdom, the non-ICT sector contributed negatively to labour productivity acceleration, offsetting the positive effects of ICT production and ICT use. The mirror-image of the slowdown in productivity growth in the non-ICT sector is the rapid acceleration in employment growth in this part of the economy during 1995-99. Only in the United States did employment expansion go together with a substantial gain in labour productivity. These effects may relate to differences in the pace of structural reforms in labour and product markets (McGuckin and van Ark 2001).

In conclusion, despite a somewhat smaller role for ICT-producing industries and a moderate positive growth effect from intensive ICT-using industries, the core of the productivity problem in Europe, Canada and Japan seems to lie as much in the non-ICT sector of the economy as in the intensive ICT-using industries. In Europe the recent employment expansion has not been accompanied by the creation of employment in sectors with rapid productive growth in the way that it has in the United States. Hence we now shift our focus to another type of investment, one that is cur-

TABLE 6

Contribution by Sector to Labour-Productivity Growth, Selected OECD Countries, 1990-1995 and 1995-1999 (in percentage points)

	ICT-producing Sector	ICT-using Sector	Non-ICT Sector	Total Economy
Canada (1990-1995)	0.2	0.3	0.7	1.2
Canada (1995-1999)	0.3	0.4	0.3	1.0
Acceleration/deceleration	0.1	0.1	-0.4	-0.2
Denmark (1990-1995)	0.3	0.2	1.6	2.0
Denmark (1995-1999)	0.2	0.6	0.2	1.0
Acceleration/deceleration	-0.1	0.4	-1.4	-1.0
Finland (1990-1995)	0.6	0.1	2.7	3.3
Finland (1995-1999)	1.4	0.6	0.7	2.7
Acceleration/deceleration	0.8	0.5	-2.0	-0.6
France (1990-1995)	0.2	0.2	0.8	1.1
France (1995-1998)	0.4	0.2	0.7	1.3
Acceleration/deceleration	0.2	0.0	-0.1	0.2
Germany (1991-1995)	0.1	0.5	1.5	2.1
Germany (1995-1998)	0.4	0.5	0.7	1.7
Acceleration/deceleration	0.3	0.0	-0.7	-0.4
Italy (1990-1995)	0.2	0.5	1.1	1.8
Italy (1995-1999)	0.3	0.2	0.1	0.6
Acceleration/deceleration	0.1	-0.3	-1.0	-1.2
Japan (1990-1995)	0.3	0.4	0.1	0.8
Japan (1995-1998)	0.4	0.3	0.1	0.8
Acceleration/deceleration	0.1	-0.1	0.0	0.0
Netherlands (1990-1995)	0.1	0.3	0.9	1.3
Netherlands (1995-1999)	0.5	0.6	-0.2	0.9
Acceleration/deceleration	0.4	0.3	-1.1	-0.3
United Kingdom (1990-1995)	0.4	0.6	1.5	2.5
United Kingdom (1995-1999)	0.6	0.5	0.1	1.2
Acceleration/deceleration	0.2	-0.1	-1.4	-1.3
United States (1990-1995)	0.3	0.3	0.5	1.2
United States (1995-1999)	0.6	1.4	0.5	2.5
Acceleration/deceleration	0.3	1.1	0.0	1.3

Source: Van Ark (2001*b*) and McGuckin and van Ark (2001).

rently seen as an important engine of growth, the creation of intangible capital.

INTANGIBLE CAPITAL: THE MISSING LINK?

The creation of a knowledge-based economy is now at the top of the economic policy agenda in many industrialized nations. For example, the Lisbon Declaration of the European Union in spring 2000 identified the knowledge-based economy as key to the creation of a competitive economy.[17] Policy-oriented organizations such as the OECD have made the investigation of knowledge creation a priority on their research agenda.[18] The academic literature has also given renewed attention to the contribution of intangible capital to growth, even though the topic is not at all new.[19] The renewed urgency to deal with the issue is partly related to the rise of ICT. ICT is a typical general purpose technology, characterized by its broad scope of applications across the economy and its ability to generate a continuous stream of cost-reducing innovations (Bresnahan and Trajtenberg 1995). Its successful diffusion is facilitated by investment in human capital, knowledge capital and organizational capital, together labelled "investment in intangible capital" (Brynjolfsson and Hitt 2000).

Despite its acknowledged importance, the problems concerning the conceptualization of intangible capital, and its measurement and integration into a production function or growth accounting framework, are still huge and largely unresolved. Various definitions of intangible capital are possible with different coverage, but most are offsprings of Schumpeter's (1934) classification, including the development of new products and production processes, organizational change, management, marketing and finance. A distinction can be made between narrow and broad concepts of intangible capital. The narrow concept deals mainly with human capital and knowledge capital (see Figure 2). With the rise of "new growth theory" in the 1980s and 1990s, these components are now well rooted in mainstream neoclassical growth theory. New growth models have improved the modelling of increasing returns and interactions among input variables that are typical of intangible assets. The broad concept of intangible capital emphasizes the facilitative role of intangible capital in the search for new technologies. It assigns a clear role to the attributes of the entrepreneur and his or her ability to raise organizational capital.[20]

From the growth accounting perspective that is pursued in this paper, the narrower concept of intangible capital is more attractive because of its roots in the production function and its focus on measurement of human capital and knowledge capital at the macroeconomic or industry level.[21] Howitt (1996) argues that knowledge creation can be treated as capital formation because it "can be produced, exchanged and used in the production of other goods, or in the production of itself. It can also be stored, although subject to depreciation, as when people forget or let their skills deteriorate, and subject also to obsolescence, as when new knowledge comes along to supersede it" (99-100). Diewert (2001) clearly defines knowledge in the context of production theory as "the set of input and output combinations that a local establishment could produce…[in a] given time period *t*" (93). Hence, investment in knowledge capital refers to an outward shift of the traditional production function referred to above in the section on the role of ICT capital.

For both Howitt (1996) and Diewert (2001), the inherent measurement problems of intangible capital go beyond those of tangible capital, despite their similar characteristics. Howitt classifies these measurement problems as follows:

The knowledge-input problem. This concerns the measurement of the resources devoted to the creation of knowledge, which often cannot be distinguished unambiguously from other inputs, such as labour and capital.

The knowledge-investment problem. This refers to the output of the process of knowledge creation, which typically is not measured at all because knowledge does not for the most part produce a commodity or service.

The quality-improvement problem. This relates to the need to pick up on improvements in goods and services that result from knowledge creation. It is an inherent part of the criticism of official statistical measures of prices and real output

FIGURE 2

Classification of Intangible Capital

a) Human capital
- a-1 Formal education
- a-2 Company training

b) Knowledge capital
- b-1 Research and development
- b-2 Patents
- b-3 Licences, brands, copyrights
- b-4 Other technological innovations, not related to b1, b2 and b3
- b-5 Software
- b-6 Mineral exploration
- b-7 Experience

c) Organizational capital
- c-1 Engineering design
- c-2 Organization design
- c-3 Construction and use of databases
- c-4 Remuneration of innovative ideas

d) Marketing of new products

e) Social capital

Source: Based on Vosselman (1998) and Young (1998).

growth and has induced major statistical programs to improve their measurement methods.[22]

The obsolescence problem. This refers to the need, with any type of capital, to find a measure of depreciation, which is very difficult for intangible capital measures.

So far there has been little attempt to measure intangible capital beyond human capital.[23] Measures of knowledge capital have not gone much beyond the accumulation of R&D expenditure combined with some rough assumptions about its price and depreciation pattern (Griliches and Cockburn 1988). To my knowledge there are no available international comparisons of organizational capital. Moreover, it is difficult to distinguish investment from operating expenses on intangibles. Finally, measurement problems also arise because intangible investments relate to services rather than goods. In conclusion, then, the stock or flow of intangible assets is not easily measured.

The latest international comparisons of intangible expenditure — as opposed to investment or capital — were conducted under the auspices of the OECD by Croes (2000) and Khan (2001). But even Khan, whose work probably represents the state of the art in this area, applies a fairly narrow concept of intangible capital, which includes measures of investment in higher education (including private expenditure), R&D (including the capital expenditure component) and software.[24] Khan adjusted the estimates for the overlap in some expenditure categories, such as that between investment in higher education and R&D, between higher education and software, and between R&D and software.

One simple way to observe the extent to which international differences in investment in intangible capital relate to diversity in productivity performance is to compare rankings of productivity estimates, the share of ICT-producing and ICT-using industries in GDP, and the share of knowledge investment shown in Table 7 of this paper. As discussed in an earlier section, minor differences in relative levels should not be reflected as different rankings. The rankings in Table 7 are therefore indifferent for between-country differences in productivity of less than 2.0 percentage points, differences in the combined ICT production and use share of less than 1.0 percentage points, and differences in the share of knowledge expenditure in total GDP of less than 0.2 percentage points.

The United States ranks second in terms of intangible-investment intensity and between third and sixth in terms of productivity (i.e., its productivity ranking cannot be distinguished from that of France, the Netherlands or Ireland).

TABLE 7

Rankings of Labour Productivity and Income levels, ICT Output Shares and Knowledge Investment/Output Ratios, OECD Countries

	Labour Productivity		Output Share of ITC Producers and Users		Investment in Knowledge as % of GDP (1998)				
	2001 (1996 US$)	rank[1]	%-share 1999	rank[2]	R&D	software	higher education	total	rank[3]
Belgium	112.4	1			1.9	1.4	0.4	3.7	13-16
Norway	109.7	2			1.7	1.2	1.0	4.0	9-14
France	101.8	3-4	24.7	9	2.2	1.2	0.8	4.1	9-14
Netherlands	100.9	3-4	30.9	2	2.0	1.7	0.7	4.3	9-11
United States	100.0	3-6	32.3	1	2.6	1.5	1.9	6.0	2
Ireland	98.4	5-6			1.4	0.5	1.1	3.1	17-18
Austria	95.9	7			1.8	0.9	0.8	3.5	15-17
Denmark	93.5	8-9	23.9	10	1.9	1.5	1.1	4.6	6-8
Germany	92.5	8-9	26.1	6-8	2.3	1.2	0.7	4.2	9-12
Italy	88.0	10-11	27.1	4-5	1.0	0.5	0.6	2.1	20-21
Finland	86.3	10-12	25.9	6-8	2.9	1.2	1.1	5.2	3-4
Switzerland	85.8	11-12			2.8	1.5	0.5	4.8	5-8
Canada	82.6	13-15	25.7	6-8	1.6	1.6	1.5	4.7	6-8
Australia	82.0	13-15			1.5	1.2	1.2	3.9	11-15
Sweden	81.7	13-15			3.8	1.9	0.8	6.5	1
United Kingdom	79.5	16	29.4	3	1.8	1.3	0.8	3.9	11-15
Spain	75.6	17			0.9	0.5	0.8	2.2	20-21
Japan	72.1	18	27.7	4-5	3.0	1.1	0.6	4.7	6-8
New Zealand	60.8	19							
Greece	58.5	20			0.6	0.2	0.9	1.7	22-23
Portugal	52.1	21			0.6	0.4	0.8	1.8	22-23
Hungary	47.2	22			0.7	1.0	0.8	2.6	19
Korea	41.1	23			2.6	0.4	2.2	5.2	3-4
Czech Republic	39.0	24			1.3	1.2	0.8	3.3	16-18
Mexico	32.8	25			0.4	0.4	0.7	1.5	24
Poland	32.2	26							
Turkey	27.5	27							
OECD	76.5				2.2	1.2	1.2	4.7	
European Union[4]	87.4				1.8	1.0	0.7	3.6	

[1] Countries within a 2%-point productivity range were ranked the same.
[2] Countries within a 1%-point ICT-share range were ranked the same.
[3] Countries within a 0.2%-point knowledge-intensity range were ranked the same.
[4] European Union is weighted average for 14 EU member countries, excluding Luxembourg.
Note: Knowledge investment includes R&D (including capital expenditure), higher education (including private expenditure) and software, and is adjusted for overlap between investment in higher education and R&D, between higher education and software, and between R&D and software.
Source: GGDC Total Economy Database, van Ark (2001*b*), Khan (2001), OECD Science, Technology and Industry Scoreboard, 2001.

The US measure is particularly high because of its expenditure on higher education (1.9 percent, against 1.2 percent for the OECD as a whole and 0.7 percent for the European Union). Moreover, the United States also stands out in terms of its share (the largest) of ICT-producing and intensive ICT-using industries in total GDP. But the relation between relative productivity levels and intangible investment is far from perfect. Indeed the country with the highest level of intangible capital, Sweden, ranks between 13th and 15th in terms of productivity. Moreover, the two countries with productivity levels similar to Sweden's (Canada and Australia) rank much lower in knowledge intensity. Sweden's high R&D intensity is the main reason for its high ranking, which can also be said of Finland and Korea. Canada's sixth to eighth position on the ladder of intangible expenditures is — as with the United States — due to its high expenditure on higher education.

Table 8 looks at the dynamics of the relation among the acceleration in productivity growth, the combined contribution of ICT production and ICT use to labour-productivity growth, and the growth in knowledge expenditure. At first sight this picture looks somewhat better than that for levels. Greece and Ireland, which are among the countries with the greatest accelerations in labour productivity during the second half of the 1990s, also show the fastest growth in intangibles. However, Greece and Ireland are typical catching-up countries, so their rapid growth on both indicators — starting from relatively low levels — comes as no surprise. The United States, which ranks between fifth and seventh in terms of productivity acceleration, ranks between ninth and 15th in terms of growth in knowledge expenditure. Sweden, Finland and Denmark score high on growth in knowledge expenditure, all ranking between third and eighth, but much lower on acceleration of productivity growth during the second half of the 1990s.

It can be concluded that the crude comparisons shown here do not suggest a clear-cut story on the role of intangibles in explaining the recent growth differentials among OECD countries. However, it should be emphasized that these measures relate only to those components of intangible capital that are easy to quantify (R&D, software, education). More importantly, these measures are likely to be most strongly related to tangible investment in new high-tech equipment, such as IT and communications equipment, which complicates the explanatory growth story — an issue briefly touched upon earlier in this paper.

The measures for intangible expenditure used so far do not include various other components of the broad definition of intangible capital, especially organizational capital. Indeed micro research suggests that the successful implementation of ICT is greatly facilitated by investment in organizational capital. For example, a 1996 Danish study showed that the growth in productivity brought about by ICT is four or five times greater if it also involves changes in work-floor methods. Norwegian research has shown that the returns on physical capital are 50 percent higher if the investment in ICT is accompanied by a comprehensive ICT strategy within the particular organization (UNICE 2001). A recent study by Brynjolfsson and Hitt (2000) of 800 US firms found that the overall expenditure on non-material capital that firms must make when introducing ICT is at least 10 times greater than the expenditure on ICT itself.

More recently, Yang and Brynjolfsson (2001) argue that the omission from the growth accounts of expenditures associated with the creation of intangible assets is a main reason for the productivity slowdown which began in 1973. If these expenditures relative to ICT investment have remained constant, then the recent productivity surge may have been underestimated. To make their case, Yang and

TABLE 8

Rankings of Labour-Productivity Growth and Acceleration, Acceleration of ICT Contribution to Productivity Growth and Growth in Knowledge Investment, OECD Countries

	Change in Growth Rate of GDP Per Hour Worked		Contribution of ITC Producers and Users to Acceleration of Labour Productivity (percentage points)		Growth in Knowledge Investment	
	1995-2001 over 1990-95	%-share rank[1]	1995-99 over 1990-95	rank[1]	1991-98	rank[2]
Mexico	3.1	1				
Czech Republic	2.2	2				
Greece	1.9	3			10.1	1-2
Ireland	1.5	4			10.2	1-2
United States	0.9	5-7	1.4	1-2	3.9	9-15
Austria	0.8	5-7			6.3	4-8
Switzerland	0.8	5-7			3.2	10-16
Turkey	0.0	8-14				
Japan	0.0	8-14	0.0	7-10	2.6	14-17
Australia	-0.1	8-14			4.0	9-14
Belgium	-0.1	8-14				
Netherlands	-0.2	8-17	0.7	3	3.8	9-15
Poland	-0.2	8-17				
Sweden	-0.2	8-17			7.6	3-4
New Zealand	-0.3	10-19				
Finland	-0.3	10-19	1.3	1-2	6.8	3-5
Canada	-0.4	12-19	0.2	4-9	2.6	14-17
France	-0.5	12-19	0.2	4-9	3.0	11-17
Hungary	-0.5	12-19			1.6	17-18
United Kingdom	-0.8	20	0.1	4-9	3.6	9-15
Denmark	-1.2	21-22	0.3	4-8	5.9	4-8
Korea	-1.4	21-23				
Portugal	-1.6	22-25			5.4	5-8
Norway	-1.7	23-25			5.6	5-8
Germany	-1.7	23-25	0.3	4-8	2.2	15-18
Spain	-2.2	26-27			4.3	9-13
Italy	-2.3	26-27	-0.2	9-10	-0.6	19
European Union[3]	-1.2				3.1	
OECD	0.1				3.4	

[1] Countries within a 0.2%-point range of productivity acceleration were ranked the same.
[2] Countries within a 0.2%-point knowledge-intensity growth range were ranked the same.
[3] European Union is weighted average for 14 EU member countries, excluding Luxembourg.
Note: Knowledge investment includes R&D (including capital expenditure), higher education (including private expenditure) and software, and is adjusted for overlap between investment in higher education and R&D, between higher education and software, and between R&D and software. See Khan (2001), Figure 6, for a breakdown by subcategory.
Source: GGDC Total Economy Database, van Ark (2001*b*) and Kahn (2001).

Brynjolfsson combine traditional growth accounting with the q-theory of investment. In this way the market valuation of the assets represents their tangible and intangible value. This methodology has not yet been applied to international comparisons.

CONCLUSIONS

We have reviewed some of the reasons for differences in growth performance and changes in the income and productivity gaps among OECD countries. The United States has continued to enjoy the highest per capita income of all OECD countries. Despite their faster GDP growth, most countries have seen little or no narrowing of the per capita income gap between them and the United States over the past decade (see Chart 1). Before the mid-1990s the reasons for the failure to narrow this gap were related to the underperformance of the labour market, which offset the catch-up effects in terms of productivity growth in the follower countries. However, for the period 1995-2001 sluggish productivity growth seems to one of the main causes of slower growth in Europe, Japan and Canada.

Using a conceptual framework, which is rooted in a traditional growth accounting framework — but with several extensions — we focused on two sources of growth differentials. First we looked at the role of the "new economy," in the sense that ICT has been a source of faster productivity growth in the United States. Then we looked at the impact of the creation of intangible capital, which has been identified as a necessary condition for exploiting the productivity advantages of ICT investment.

The analysis suggests that differential realization of the potential to generate productivity accelerations from ICT has contributed to the differential economic growth performance among OECD countries. At the same time, it is difficult to precisely measure the contribution of the various factors at the macroeconomic level. One may even argue that the traditional methods for analysing and measuring the relation between inputs and output at the macroeconomic level are, increasingly, failing to describe the processes that drive changes and differences in growth performance between firms. Nevertheless, the past several years have seen significant advances in growth theory and improvements in measurement methods, even though it is probably true that formal theory is ahead of conceptual clarity and reliable measurement (Howitt 1996). This paper has identified some areas for further research, such as the need to improve the measurement of ICT capital as well as the analysis of its contribution to growth, to extend measures of intangible capital to organizational capital, and to disaggregate input and output measures to the level of industries.

Macroeconomic analysis and measurement of sources of growth remain crucial to our understanding of the relation among economic growth, improvement in living standards and social progress. Per capita income is a reasonable — though imperfect — proxy for living standards, one that is fairly comparable across countries. Many sources of economic growth are themselves direct contributors to improvements in living standards and social progress. For example, the creation of human capital and the creation of knowledge are important determinants of social progress, and income growth provides feedback on the demand for such assets. Efficient allocation of such scarce resources is essential for full exploitation of this potential in order to raise living standards and drive social progress.

NOTES

This paper was written while I was a Visiting Fellow at the Economic Growth Center at Yale University. Parts of the paper are based on earlier work, including van Ark (2001*a*, 2001*b*), van Ark and McGuckin (1999), and McGuckin and van Ark (2001, 2002). I am grateful to Thomas Rymes, Andrew Sharpe and other

participants at the IRPP-CSLS workshop "Productivity and Social Progress in Canada: Perspectives and Prospectives" for their helpful comments.

1 See, for example, various issues of the United Nations *Human Development Report*. See also Banting, Sharpe and St-Hilaire (2001).

2 See van Ark (2001*a*) for a more extensive discussion.

3 The 2001 numbers are preliminary figures based on estimates of output and employment from *OECD Economic Outlook* (December 2001).

4 It should be noted that the productivity growth rates for Canada differ from other estimates, which show that productivity growth rates in the Canadian business sector have not decelerated since the mid-1990s (see, e.g., Sharpe's contribution in this volume). The estimates in Table 1 and throughout the remainder of this paper refer to the total economy.

5 For all underlying data and a complete description of sources, see the GGDC Total Economy Database (http://www.eco.rug.nl/ggdc/*index-dseries.html*). All dollar-based estimates are expressed at 1996 price levels. This price measure is preferable because all national currency estimates are converted to US dollars on the basis of purchasing power parities (PPP) for 1996 (OECD 1999). It should be emphasized that exact rankings of these estimates are hazardous given the margin of error involved. Countries within a range of 1-2 percent in terms of productivity and per capita income cannot really be distinguished. See also the final section and Tables 7 and 8. There can be slight differences between the data used here and the data from national statistical offices. Our measures are largely derived from OECD sources (national accounts and labour force statistics). These are most comparable internationally but can differ from national sources because the OECD numbers may be less current or somewhat differently defined. For example, in the case of Canada, mainly because of a lower GDP growth estimate for 2001, the productivity growth rates from the GGDC database are lower than those from Statistics Canada for the period 1995-2001, and therefore show somewhat greater deceleration compared to the early 1990s.

6 However, there are also those who argue that ICT does not have the potential to increase growth by as much as the great innovations of the early 20th century, such as electricity and the combustion engine (Gordon 2000). In addition, Gordon stresses that part of the growth acceleration in the United States is due to pro-cyclical productivity in the upward phase of the business cycle during the second half of the 1990s. Indeed, it is only after a complete cycle has passed that one can fully evaluate the growth impact of ICT.

7 There are as yet no studies available on ICT investment and its contribution to growth for the whole of the European Union. See Daveri (2001) for a study of proxy estimates of ICT investment based on expenditure information. See van Ark et al. (2002) for provisional estimates of ICT investment in 12 out of 15 EU member states.

8 In principle, equation (3) can also be rearranged to obtain the rate of change of labour productivity: $\hat{Q} - \hat{L} = s_{KN}(\hat{K}_N - \hat{L}) + s_{KC}(\hat{K}_C - \hat{L}) + \hat{A}$. It should be recognized that K_C and K_N represent the annual services that ICT capital and other capital goods deliver to output growth, which are weighted at the user cost of individual assets. The latter consist of the gross rate of return times the current price of the given asset. Gross rates of return on ICT capital are typically high to compensate for the rapid price declines of ICT goods. Hence the rapid growth of individual capital services from ICT and the rapidly increasing weights at which these enter the overall measure of capital services account for the increasing contribution of ICT capital to growth (see Schreyer 2000; Colecchia and Schreyer 2001).

9 Finland is a special case, however, as the production of communications equipment is a dominant feature of its manufacturing sector.

10 See van Ark (2002) for a review. At the national level, except for the United States, growth accounting studies with ICT as a separate input, and based on actual investment data instead of reworked expenditure data, were carried out for Finland (Jalava and Pohjola 2001), France (Cette, Mairesse and Kocoglu 2001), the Netherlands (van der Wiel 2001) and the United Kingdom (Oulton 2001). The overall picture suggests that most countries show somewhat lower contributions of ICT to economic growth than the United States, the one exception being Finland.

11 As a result, if there are any supra-normal returns on ICT capital, these end up in the TFP residual. See Schreyer (2000) and Stiroh (2002) for a discussion of this issue.

12 Here, one speaks of an assumption of Harrod-neutral technical change, keeping the capital-output ratio rather than the capital-labour ratio constant. More specifically, following the Harrod-Rymes concept of technical change, the larger investment in ICT will not reduce growth of total factor productivity, but rather will raise it, as ICT improves the efficiency by which the capital goods themselves are produced.

13 The distinction between intensive ICT-using industries and non-ICT industries is largely based on studies by McGuckin and Stiroh (2001) and the National Science Foundation (2000) for the United States. See Table 4 in van Ark (2001*b*) for the exact classification used here. Even though ICT-producing industries are also ICT-

using industries (as the producers themselves also invest heavily in ICT), ICT-producing industries are excluded from the ICT-using sector in the analysis below. The distinction between ICT-using industries and non-ICT industries has two limitations. First, even though we use one and the same classification for all countries, ICT investment-output ratios and ICT capital shares are not necessarily distributed in the same way across countries. For example, even though retailing is within the non-ICT category in the classification used here, it would in fact fall within the ICT-using category in the United States. Second, ICT investment intensity may not always be the best criterion for determining the potential impact of ICT on productivity. In some industries even a small amount of ICT can generate high returns because of its leverage on existing activities. For example, in the oil-extraction industry a small investment in ICT has fundamentally changed the methods by which this industry explores new oil reserves (see Olewiler's contribution in this volume). Obviously the classification used here can be further tested for its sensitivity for other distributions, which is a topic for further research. See van Ark, Inklaar and McGuckin (2002) for a more refined classification and wider ranger of countries.

14 In fact seven sectors instead of three are distinguished in the weighting scheme: ICT-producing manufacturing, ICT-producing services, ICT-using manufacturing, ICT-using services, other manufacturing, other services, and remaining sectors (such as agriculture, mining, construction and public utilities). See van Ark (2001*b*).

15 For France, Germany and Japan the last period ended in 1998; for Germany the first period started in 1991.

16 In Denmark, Italy, Japan, the Netherlands and the United Kingdom the *relative* contribution of ICT production and ICT use was higher than the two-thirds contribution in the United States, but overall labour-productivity growth in these countries was much slower. The relatively rapid productivity growth in Finland is largely accounted for by ICT production.

17 See http://ue.eu.int/Newsroom/LoadDoc.asp?BID=76&DID=60917&LANG=1

18 For example, the OECD Growth Project has targeted knowledge creation as a pillar of sustainable growth. See also the OECD's *Science, Technology and Industry Scoreboard 2001* and STI Review #27 (2001).

19 See Ducharme (1998) for an overview of theory related to intangible capital, which is rooted in human capital theory, theory on technical change, intellectual capital and new growth theory. See Hill (1999) for classification issues. Howitt (1996) and Diewert (2001) deal with the conceptualization of knowledge capital in a production function framework. Mortensen (2000) also discusses the growth accounting work related to intangible capital.

20 The latter is more firmly rooted in evolutionary theory (see, e.g., Clement, Hammerer and Schwarz 1998). Recently, the literature on the sources of growth has moved a step further by looking at the creation of organizational capital not only within the firm but also within the society as a whole, so-called social capital (see, e.g., Helliwell 2001; OECD 2001*b*). Here I abstain from dealing with social capital as the problems concerning its conceptualization and measurement go beyond what can be achieved in the analytical framework I am using. It should be noted, however, that as far as OECD countries are concerned, the empirical work has so far not shown large differences in the effect of social capital on growth (Temple 1999).

21 See Mortensen (2000) for an overview of growth accounting work including intangibles.

22 Much of the criticism of official accounts, particularly price index measurement, stems from the work of Griliches (1992, 1994) and the US Advisory Commission to Study the Consumer Price Index in 1996. Recent attempts by the Bureau of Labor Statistics and the Bureau of Economic Analysis in the United States, supported by a range of studies at the Brookings Institution, as well as new work by national statistical office across the OECD and by Eurostat, have contributed to many improvements in the measurement of prices and real output to deal with quality issues, even though many issues remain unresolved. See Dean and Harper (2001) for a review of work in the United States. See van Ark (2002) for references to other work, in particular in Europe.

23 See OECD (1998) for a review of international comparisons of human capital. Kendrick (1976) is one of the first encompassing studies to measure intangible capital beyond human capital; see also Kendrick (1994).

24 Croes (2000) uses a broader concept including expenditure on private and secondary education and marketing.

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